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FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER **212701US**

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR **09/914255**

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR00/00448	**23 February 2000**	**24 February 1999**

TITLE OF INVENTION
BIDIMENSIONAL DETECTOR OF IONIZING RADIATION AND MANUFACTURING PROCESS FOR THE DETECTOR

APPLICANT(S) FOR DO/EO/US
Jean-Louis GERSTENMAYER, et al

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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☒ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

    Notice of Consideration of Documents Cited in International Search Report
    Notice of Priority, PCT/IB/304 , PCT/IB/308
    Drawings (4 sheets)
    Amended Sheet #4

PCTUS1/REV03

518 Rec'd PCT/PTO 24 AUG 2001

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/914255	INTERNATIONAL APPLICATION NO. PCT/FR00/00448	ATTORNEY'S DOCKET NUMBER 212701US

24. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1000.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$690.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	17 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$860.00**	
☐ Applicant claims small entity status. (See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$0.00**	
SUBTOTAL =				**$860.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$860.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$860.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$860.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ____________ in the amount of ____________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **15-0030** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Surinder Sachar
Registration No. 34,423

22850

Surinder Sachar
SIGNATURE

Marvin J. Spivak
NAME

24,913
REGISTRATION NUMBER

Aug. 24 2001
DATE

09/914255
518 Rec'd PCT/PTO 24 AUG 2001

212701US

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF	:	
JEAN-LOUIS GERSTENMAYER ET AL	:	ATTN: APPLICATION DIVISION
SERIAL NO: NEW U.S. PCT APPLN (Based on PCT/FR00/00448)	:	
FILED: HEREWITH	:	
FOR: BIDIMENSIONAL DETECTOR OF IONIZING RADIATION AND MANUFACTURING PROCESS FOR THIS DETECTOR	:	

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE CLAIMS

Please cancel Claims 1-17 without prejudice.

Please add new Claims 18-34 as follows:

18. (New) Bidimensional detector for incident ionizing radiation comprising primary particles whose energies are greater than or equal to 100 keV, the detector including a block of converting material configured to release secondary particles by interaction with the incident ionizing radiation, whereby a thickness of the block is at least equal to one-tenth of a mean free path traveled by the incident ionizing radiation through the converting material, the detector further including parallel slits crossing the block, the slits filled with a fluid

configured to interact with the secondary particles to produce tertiary particles equal in intensity and position to the incident ionizing radiation, whereby the block is positioned to ensure that the incident ionizing radiation comes in on a first block face where the slits terminate.

19. (New) Detector as described in Claim 18, wherein the slits are perpendicular to the first face of the block.

20. (New) Detector as described in Claim 18, wherein slit planes form an angle of between 1° and 5° with a line perpendicular to the first face of the block.

21. (New) Detector as described in Claim 18, wherein the fluid is configured to be ionized by the secondary particles, thereby producing electrons as the tertiary particles, and the detector further includes means for creating an electric field for extracting the tertiary particles from the block.

22. (New) Detector as described in Claim 21, wherein the fluid is a gas.

23. (New) Detector as described in Claim 21, further comprising means for analyzing the electrons extracted from the block.

24. (New) Detector as described in Claim 23, wherein the means for analyzing includes an avalanche gas amplifier for producing electron avalanches from the electrons extracted from the block.

25. (New) Detector as described in Claim 24, wherein the fluid is a gas and is configured to convert the electron avalanches into visible or ultraviolet radiation, and the means for analyzing includes means for detecting the visible or ultraviolet radiation.

26. (New) Detector as described in Claim 25, wherein the means for detecting the visible or ultraviolet radiation includes a camera capable of detecting the visible or ultraviolet

radiation, or a matrix of amorphous silicon photodiodes placed against the avalanche gas amplifier.

27. (New) Detector as described in Claim 21, wherein the converting material is an electrical conductor and the block is formed from stacked layers of the converting material, whereby the conducting layers alternate with electrically isolating layers and the stacked layers begin with a conducting layer of the converting material on the first face of the block and ends with a conducting layer of the converting material on a second face of the block, which is opposite the first face and on which the slits terminate, and the detector further includes means for applying electric voltages to the stacked layers, with electric voltages increasing gradually from the first face to the second face, thereby creating an electric field.

28. (New) Detector as described in Claim 27, further including a supplementary layer formed on an additional electrically isolating layer, the electrically isolating layer formed on the last layer of the converting material, located at the second face of the block, whereby the supplementary layer is made of an electrically conducting material configured to absorb the secondary particles created in the last layer and the supplementary layers have slits running through them.

29. (New) Detector manufactured according to Claim 27, wherein the layer of the converting material located at the second face of the block is blackened out to prevent parasitic light reflections.

30. (New) Detector manufactured according to Claim 21, wherein the converting material is electrically isolating, or highly resistive, and the block is created from stacked layers of the converting material, or the converting material is made from one single mass of the converting material, whereby the block further includes first and second layers or grills which are electrically conducting and formed, respectively, on the first block face and second

block face, the second block face located opposite the first block face and on which the slits terminate, and the electric field is created by raising the first layer or grill to a first voltage and the second layer or grill to a second voltage which is greater than the first voltage.

31. Detector as described in Claim 18, wherein the block is made from a stack of strips made from an isolating converting or highly resistive material, and the strips are separated from each other by spacers which define the parallel slits of the block, whereby the block further includes first and second layers or grills which are electrically conducting and formed respectively, on the first block face and second block face, the second block face located opposite the first face and on which the slits terminate, and the electric field is created by raising the first layer or grill to a first electric voltage and the second layer or grill to a second electric voltage which is greater than the first voltage.

32. (New) Manufacturing process for the detector of Claim 18, wherein the block is firstly manufactured and then the slits are manufactured by one of the following techniques:

- waterjet cutting,
- electrical discharge machining,
- roll-out stretch wire.

33. (New) Manufacturing process as described in Claim 33, wherein the layers are stuck to each other.

34. (New) Manufacturing process as described in Claim 33, wherein, before creating each slit, a guide hole is made in the block which is then used to create the slit.

IN THE ABSTRACT OF THE DISCLOSURE

Please amend the abstract on page 30 as follows:

ABSTRACT OF THE DISCLOSURE

Bidimensional detector of ionizing radiation and manufacturing process for the detector. The detector includes a block created from a material which releases secondary particles by interaction with incident ionizing radiation with an energy level greater than or equal to 100 keV. The thickness of the block is at least equal to one-tenth of the mean free path traveled by the incident ionizing radiation particles in the material. Parallel slits run through the block and the slits are filled with a fluid configured to interact with the secondary particles to produce other particles representing the radiation. The block, and then the slits, are formed, for example, by waterjet cutting, electrical discharge machining, or roll-out stretch wire. The bidimensional detector can be used, for example, for radiographic purposes.

REMARKS

Favorable consideration of this application, as presently amended, is respectfully requested.

The present preliminary amendment is submitted to place the above-identified application in more proper format under United States practice.

By the present preliminary amendment original Claims 1-17 are cancelled and new Claims 18-34 are presented for examination. New Claims 18-34 are deemed to be self-evident from the original disclosure, including original Claims 1-17, and thus are not deemed to raise any issues of new matter. Any differences between new Claims 18-34 and original Claims 1-17 are believed to at most broaden the scope of new Claims 18-34.

The Abstract has also been amended by the present response to be in more proper format under United States practice.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.

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212701US

Marked-Up Copy
Serial No:

Amendment Filed on:
8-24-2001

IN THE CLAIMS

Claims 1-17 (Cancelled).

Claims 18-34 (New).

IN THE ABSTRACT OF THE DISCLOSURE

Please amend the abstract as follows:

-- ABSTRACT OF THE DISCLOSURE

Bidimensional detector of ionizing radiation and manufacturing process for [this] the detector.

[This] The detector [consists of] includes a block [(2)] created from a material which releases secondary particles by interaction with incident ionizing radiation [(9)] with an energy level greater than or equal to 100 keV. The thickness of the block is at least equal to one-tenth of the mean free path traveled by the incident ionizing radiation particles in the material. Parallel slits [(14)] run through the block [which] and the slits are filled with a fluid [capable of interacting] configured to interact with the secondary particles to produce other particles representing the radiation. The block, and then the slits, are formed, for example, by waterjet cutting, electrical discharge machining, or roll-out stretch wire. The [invention] bidimensional detector can be used, for example, for radiographic purposes.--

09/914255
518 Rec'd PCT/PTO 24 AUG 2001

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THE FOLLOWING IS THE ENGLISH TRANSLATION OF THE ANNEXES TO THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT : AMENDED SHEET (Page 4).

09/914255
518 Rec'd PCT/PTO 24 AUG 2001

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BIDIMENSIONAL DETECTOR OF IONIZING RADIATION AND MANUFACTURING PROCESS FOR THIS DETECTOR.

DESCRIPTION

TECHNICAL DOMAIN.

The present invention concerns a detector of ionizing radiation as well as a manufacturing process for this detector.

The ionizing radiations which can be detected by the invention can contain X-rays, photon gammas, protons, neutrons or muons.

The detector, subject of the current invention, is capable of converting incident ionizing radiation into other particles, which are themselves ionizing (electrons for example) and are easier to work with than the incident ionizing radiation.

In particular, the invention may be used in the following sectors:

- instantaneous radiography of highly absorbing and/or voluminous objects.
- ultra rapid cineradiography of mechanical mobiles
- positioning of patients in radiotherapy.
- neutronography.
- protonography.
- medical and biological imagery (tomographies by emission of positrons),

- imagery by coded apertures to inspect voluminous objects with low radioactivity or suspicious parcels in a passive or quasi-passive manner.

PREVIOUS STATE-OF-THE-ART

The bidimensional ionizing radiation detector's which are already exist feature plates made of heavy metal such as lead, or, some other metal, with a high cross-section factor, that is, a large surface of interaction with the incident ionizing radiation.

For example, it is common to use a metal with an atomic number (Z) greater than or equal to 73 to detect X- or gamma-ray photons and a metal with an atomic number (Z) generally less than 14 or greater than 90 to detect neutrons.

Other materials, such as Gadolinium (Z= 64) can also be used to detect neutrons.

Holes are drilled in the metal plates using either chemical or electrochemical procedures. The plates are isolated electrically from each other if necessary, that is, when plate thickness is equal to, or greater than, a few hundred micrometers.

The holes are then filled with an ionizable gas.

A high-energy incident photon (X- or gamma-) then results in the release of at least one electron in one of the detector plates, either by Compton effect or pair-creation effect.

The incident X- or gamma-ray photon causes the released electrons to move rapidly with a kinetic energy approximately equal to the incident photon. The electron then rapidly ionizes some gas molecules contained in one of the holes which the electron reaches and, generally, passes through. Slow secondary electrons which are removed from these molecules due to the ionization of the molecules, are routed along this hole and then collected by means of an electric polarization field (bias), also referred to as a drift field. The slow secondary electrons are then detected in, for example, an ionization chamber or in a proportional avalanche chamber.

Such bidimensional detectors are described in documents [1], [2], [3], [6], and [7] which, like all other documents referenced hereafter, are listed at the end of the present description.

The decision to use a whole-detection system can be explained by the fact that such systems offer a very high degree of spatial resolution and offer a high level of performance, subject to the holes being perfectly formed and sufficiently large.

The holes are created by means of chemical etching. This procedure is preferable to waterjet cutting which suffers from the disadvantage of generating a frontal shock when the waterjet is opened to begin drilling the holes.

This frontal shock chips the material in which the holes are to be cut, which splits the material and makes it unfit for use.

However chemical etching is an expensive and slow process.

Moreover, the quantity of secondary electrons collected, and by extension, the performance levels of hole-system detectors are limited since only between 10% to 30% of the secondary electrons created in the course of each gas ionization are collected.

This can be explained by the fact that chemical etching does not create holes whose interior walls are perfectly cylindrical, that is, it cuts bottlenecks in the holes which in turn causes the electric field lines to be deformed and reduces the useful diameter of the holes. Thus, the performance levels of hole-system detectors are low.

PRESENTATION OF THE INVENTION.

The objective of the present invention is to remedy the aforementioned inconveniences of hole-based detectors (that is, expensive and low performance levels). The present invention proposes to meet this objective by using slits instead of holes. US 4150315 describes a radiographic device for the detection of low-energy x-rays.

To reformulate the above in a more precise manner; the objective of the present invention is an bidimensional ionizing radiation detector for the intended for use with incident radiation consisting of primary particles whose energies are greater than, or equal to 100 keV. Furthermore, the detector includes a block featuring a converting material capable of releasing secondary particles by interaction with the incident ionizing radiation, whereby the thickness of the block is at least equal to one-tenth of the mean free path traveled by the primary particles of the incident radiation in the material. The detector is characterized by the fact that it has parallel slits running across the block, which are filled with a fluid capable of interacting with the secondary particles to produce tertiary particles equal in intensity and position to the incident radiation, whereby the block is positioned in such a manner as to ensure that the incident radiation comes in on a first face where the slits terminate.

These slits divide the block into strips.

The detector (subject of the invention) is far less expensive to manufacture than the hole-system detectors previously mentioned.

Moreover, it is reasonable to expect that the detector's level of performance and spatial resolution will be far better then the hole-based system.

The detector (subject of the invention) is also easy to manufacture, and offers a far bigger useful detection surface.

Under a first specific manufacturing mode, the slits of the detector (subject of the invention) are perpendicular to the first block face.

Under a second specific manufacturing mode, the slits planes create an angle of between 1 ° to 5 ° with a line perpendicular to the first block face.

Under a specific manufacturing mode of the detector (subject to the invention), the fluid in the slits may be ionized by secondary particles (for example, energetic electrons produced by Compton effect), thereby causing the fluid to produce electrons by ionization which may be considered tertiary particles. Furthermore, the detector includes the technology required to create an electric field capable of extracting these electrons from the block.

To this end, an ionizable gas is used, for example.

The detector may also feature the necessary technology to analyze the extracted electrons.

The analysis technology may include an avalanche gas amplifier, capable of producing electron avalanches from the block-extracted electrons.

In this case, an ionizable gas may be used, capable of converting the electron avalanches into visible or ultraviolet radiation, and the technology required to analyze visible or ultraviolet radiation may be integrated into the detector (subject of the invention).

The detection technology may include a camera capable of detecting the visible or ultraviolet

radiation, or a matrix of amorphous silicon photodiodes placed against the avalanche gas amplifier.

Under a first specific manufacturing mode of the invention, the material is an electrical conductor, and the block consists of stacked layers of this material, whereby these layers alternate with electrically insulating layers. Under this first version, the stack begins with a layer of conducting material on the first face of the block, and ends with a layer of conducting material on the second face of the block, located opposite the first face, and on which the slits terminate. The detector (object of the invention) also offers the necessary technology to carry the aforementioned conducting layers to electric voltages increasing from the first face to the second face in order to create an electric field.

The layer of material on the second block face can be blackened out in order to avoid parasitic light reflections, in particular, ultraviolet.

Under a second specific manufacturing mode for the invention, the material is an electric insulator (or offers high electrical resistivity) and the block consists of stacked layers of this material or alternatively, is a single mass of this material. Moreover, the block includes first and second layers or grills which are electrical conductors and are located on the first block face and second block face respectively, whereby the second block face is opposite the first face and on which the slits terminate. The electric field is

created by applying an electric voltage to the first layer or grill and a different electric voltage to the second layer of grill which is superior to the first voltage, thereby creating a drift current, from which the tertiary particles (ionization electrons) created by ionization of the fluid, may be extracted.

Under another specific manufacturing mode for the invention, the block is a stack of strips made from an isolating (or highly resistive) converting material, and separated from each other by spacers chosen so as to define the parallel block slits. Furthermore, under this option, the block includes first and second layers or grills which are electrical conductors and are located on the first block face and second block face respectively, whereby the second block face is located opposite the first face and on which the slits terminate. They electric field is created by applying an electric voltage to the first layer or grill and a different electric voltage to the second layer of grill which is superior to the first voltage.

The present invention also concerns the manufacturing process for the detector (subject to the invention).

Under the premises of this manufacturing process, the block is firstly created, after which the slits are created by choosing one of the following three techniques:

- waterjet cutting,
- electrical discharge machining, or,

- roll-out stretch wire.

Under a specific implementation mode for the procedure (subject of the invention), applicable for the manufacturing of the detector and compatible with the aforementioned first and second specific manufacturing modes (utilization of an electrical conducting material, or utilization of an insulating/highly resistive material), the layers which are used are stacked against each other.

Before creating the slits, a guide hole may be created in the block, which will be used as a basis to create the slits.

SHORT DESCRIPTION OF THE DRAWINGS

The present invention will be easier to understand from the following manufacturing samples, given by way of indication and in no way limiting. Reference is made to the following annexed drawings:

- Figure 1 is a schematic perspective view of a specific manufacturing mode for the detector (subject of the invention),
- Figure 2 is a schematic transversal sectional view of the detector of figure 1, from a Plan P, shown on the sectional view,
- Figure 3 is a schematic perspective view of a detector designed in accordance with the invention,

- Figure 4 is a schematic and partial transversal sectional view of another detector designed in accordance with the invention
- Figure 5 is a block diagram of another detector designed in accordance with the invention,
- Figure 6 is a block diagram of a variation of the detector mentioned in figure 2.

DETAILED PRESENTATION OF SPECIFIC MANUFACTURING MODES OF THE DETECTOR.

The bidimensional detector of incident ionizing for radiation energies greater than, or equal to, 100keV (as per the precepts of the invention) consists of a block (2) formed from a converting material, offering a high interaction surface area with respect to the incoming ionizing radiation.

In the case of figure 1, this material is an electrical conductor and, as may be seen on figure 2, the block itself is a stack of layers (4) of this material, whereby these layers (4) alternate with electrical insulating layers (5).

The stack begins with one of the layers (4) in the first face (7) of the block, through which the ionizing radiation penetrates into the block (2). The stack also terminates with one of these layers (4) in the second face (8) of the block, which is located opposite the first face.

In the example shown, the detector is intended to detect X-rays which have an energy of 5 MeV, for example.

An incident X- ray whose path is indicated as (9) on figures 1 and 2 interacts with the material in one of the layers (4) to produce, either by Compton effect or pair-creation effect (electron, positron), an electron with a very high kinetic energy, whose path is indicated by the arrow (10) on figure 2.

Another arrow (12) has also been used to represent the path of the photon whose energy is less than the incoming X- Ray, whereby this lower-energy photon results from the interaction of the X- Ray with the material.

The thickness of block 2 (counting from the first face (7) to the second face (8) of the block), indicated as E, is at least equal to 1/10 of the free mean path traveled by the incident X- rays in the conducting material. It is this thickness which gives the material its high halting power.

In keeping with the invention, the detector shown in figure is 1 and 2 also features parallel slits (14).

The slits of the detector shown in figure 1 and 2 have been laid out in such a way that the slits are either horizontal or, on the contrary, vertical. However this is only one possibility and other slit layouts are entirely possible, depending on the intended utilization of the detector.

The slits (14) run across the block (2) from the first face to the second face, thereby splitting up to the block into strips. The slits (14), are filled with

gas (in a manner explained later in this document), which is ionizable by the electrons resulting from the interaction of the incident X-rays with the converting conductor material.

Every electron created in this fashion interacts with the gas in a slit (14) to produce positive ions, shown by the arrow (16) and electrons, shown by the arrow (18) on figure 2.

It should be mentioned that the slits (14) which terminate on faces (7) and (8), are perpendicular to the faces (7) and (8).

The detector shown in figures 1 and 2 also features technology required to create an electric field capable of extracting from block (2) the electrons resulting from gas ionization. This is done by provoking the displacement of the electrons from the slits where they are first created towards the face (8).

The creation of the electric field as described above is illustrated in figure 2 for the electron whose path bears the reference (18).

The ion corresponding to this electron is driven towards the first face (7) under the effect of the electric field.

In the example shown in figures 1 and 2, the electric field is created by polarization techniques which raises the voltages of the layers in the conducting material (4) progressively from the first layer, located at the first block face (7) to the last layer (4), located at the second face (8).

Block (2) is placed in a hermetic enclosure (20) containing the ionizable gas.

However, instead of such a configuration, the enclosure (20) could have the necessary technology (not shown) to circulate and purify the gas.

The enclosure (20) features a radiolucent window (22) and situated opposite the first face (7) of the block (2).

In the specific example shown, the window (22) is made of aluminum, that is, a material radiolucent as regards the incident X- rays. However, if necessary, other materials can also be used.

The polarization technology used allows the voltages of the conducting material layers (4) to be raised progressively, whereby these voltages also feature series-mounted electric resistors R1, R2, ..Rn (figure 2).

It may be seen that each terminal shared by 2 series-mounted adjacent resistors is connected to one of layers (4) of the conducting material, with the first terminal of the first resistor (R1) connected to the first layer (4) of the conducting material, located opposite the window (22), whereas the second terminal of the last resistor (Rn) is connected to the last layer (4) on the conducting material, located on the second face (8) of the block (2).

These resistances are formed outside the enclosure (20) and connected to the layers (4) of the conducting material through electrically insulating passages (not

shown) in the enclosure (20). However, the resistances can also be formed inside the enclosure.

These resistors are formed, for example, by etching a conducting layer in, for example, gold, whereby this conducting layer is formed on an electrically isolating element in for example, ceramic (not shown).

The respective resistor values are adjusted by varying the thickness of this etched layer, using for this purpose, for example, laser evaporation techniques.

This results in gradually increasing electric voltages, that is, a voltage gradient with the first terminal of the first resistance (R1) at ground potential and the second terminal of the last resistance (Rn) at a high positive voltage.

The detector shown in figures 1 and 2 also features the necessary technology to analyze the electrons extracted from block (2) via the electric field, and which leave block (2) by the second face (8).

This electron analysis technology also includes an avalanche gas amplifier (24) capable of producing electron avalanches from the electrons extracted from the block (2).

As may be seen from figure 2, this amplifier (24) has 2 electrically conducting grills (26 & 28) which are placed in the enclosure (20), at the second face (8) of block (2) and which are parallel both to each other and to this second face (8).

The first grill, that is, the one nearest the second face (8) is raised up to a positive voltage, superior to

the voltage applied to the second terminal of the last resistor (Rn), and the second grill (28) is raised up to a positive voltage, superior to the voltage applied to the first grill (26).

In the example shown, the first and second grills are raised up to a voltage of 10 kV and 16 kV respectively, whereas the layer (4) nearest the window (7) is earthed and the layer (4) nearest the grill (26) is raised to a voltage of 8kV.

Other types of electron have lunch amplifiers can also be used; for example PPAC, "Micromegas" (see documents [4] and [5]) or GEM.

Attention is drawn to the fact that and ionizable gas is a mixture of:

- a gas, for example, Argon allowing for the multiplication, by avalanche, of electrons extracted from block 2.
- a gas, for example, dimethyl ether, or DME, allowing for the avalanche amplification coefficient to be controlled,
- a gas or vapor, for example, triethylamine or TEA, capable of scintillation from the electron flow in the avalanche.

One possibility of such a mixture, by no means the only such possibility, is a mixture consisting of 86% Argon, 20% DME, and 2% TEA.

Examples of avalanche gas amplifiers are given in the documents [4] and [5].

Every electron leaving the block (2) via the second face (8) of the block (2) is successively accelerated by the conducting grills (26 & 28), thereby creating an electron avalanche (29), concentrated essentially between these two grills.

Moreover, this avalanche results in an ultraviolet radiation (30) by interaction with the TEA.

The enclosure (20), opposite the second grill (28) features a window (32) which is radiolucent with respect to this ultraviolet radiation (made out of quartz, for example).

Outside the enclosure (20), opposite this quartz window (32), a camera (34) capable of detecting the ultraviolet radiation (30) is fitted.

Naturally, if the chosen gas mixture gives off visible radiation by interaction with the electron avalanche, then the camera chosen must be capable of detecting this visible radiation and the material used in the window (32) must be radiolucent with respect to this radiation.

Moreover, instead of using a camera, a matrix of amorphous silicon photodiodes (not shown) may also be used to detect the visible or ultraviolet radiation resulting from the interaction of the gas mixture with the electron avalanches.

In this case, the matrix is affixed against grill (28), which increases compactness and reduces weight.

Parasitic reflections of visible or ultraviolet light can be avoided by, for example, oxidizing the appropriate metal, and so blacking out the face of the layer (4) located opposite the grill (26).

The block (2) shown in figures 1 and 2 can be replaced by the block (36), whose perspective is represented in figure 3.

In the case of figure 3, an electrically isolating material (for example, ceramic, glass, or plastic material), or highly resistive material (for example, ceramic material or oxide (resistance at least equal to $10^5\Omega$.cm) where block (36) is a stack of layers (37) of this material, or can alternatively, be made from one single mass of this material.

In the case of figure 3, block (36) also features a first conducting layer (38) and a second conducting layer (40) formed respectively, on the first face and the second face of block (36).

The conducting layers (38 & 40) can be replaced by conducting grills.

Figure 3 also shows the parallel slits (14) running across the block (36), which are perpendicular to the first and second block faces. These slits divide the block into strips.

In this case, the electric field is generated by using technology (not shown) capable of raising the second conducting layer (40) to a high positive voltage, whereby the first conducting layer (38) is grounded.

One possible configuration, but by no means the only possibility, is: layers (4) are in tungsten and layers (6) are in kapton (trademark), the distance between the second face (8) and the first grill (26) is 1.5 mm and the distance between the two grills (26 & 28) equals 3 mm, the thickness of block (2) or block (36) is 30 mm, the thickness of the conducting layers (4) is 250 μm, the thickness of the isolating layers (6) is between 50 μm to 500 μm, the thickness of the conducting layers (38 & 40) is 10 μm, these conducting layers (38 & 40) are in copper, the width of the slits (14) is 500 μm, their length (L) varies from 10 cm to 50 cm and these slits are separated from each other by about 700 μm.

Instead of tungsten, lead or depleted uranium (uranium 235) could also be used to form layers (4).

Instead of being perpendicular to the first face (7) of block (2) or block (36), the slits (14) or, more precisely, the slits' planes, that is, the mid-perpendicular planes of the slits, which extend more or less depending on the slits (14) - shown as (X) in the section plan of figure 4 - can create an angle (□..of between 1 ° and 5 ° with a plane (shown as Y), which is perpendicular to this first face (7) as illustrated in figure 4.

This has the advantage of increasing the stopping power applied to the incident ionizing radiation, subject to the detector being turned in such a way that the incoming radiation arrives at face (7) of block (2) or

block (36), and in a direction perpendicular to the layers (4) or (38).

Moreover, it should be noted that the thickness of blocks (2) and (36) is chosen on the basis of the desired stopping power.

Moreover, the dimensions of the slits (14) and the layers in blocks (2) or (36) are chosen to optimize the spatial resolution of the corresponding detector, and the performance level of this detector, that is, the quantity of electrons generated in the slits.

It should be noted that, under the previous state-of-the-art, the total thickness of the metal plates (cumulative total with incident ionizing radiation) was chosen so as to make metal plate etching possible.

In the detector of figures 1 and 2, and likewise in 3, the total thickness of the layers in blocks (2) or (36) is entirely determined by operating limitations imposed by the electric field (or more precisely, the electrostatic field).

These layers can be very thin or, on the contrary, very thick since, in both cases, slits can still be used.

Using slits such as described in this document, instead of holes, dramatically improves the detector's performance level (that is, quantity of electrons generated in the slits) but also, and more surprisingly, the spatial resolution of the detector.

As shown by figure 2 the spatial resolution along the direction D 1 perpendicular to slits (14) is determined by the gap between these slits, and although

electrons do drift inside the slits along a direction D2 (perpendicular to D1), experiments show that this electron drift is not very considerable; in fact, the width of the probability distribution for this drift at mid-height is less than the gap between the slits (14) with a slit gap equal to, for example, 500 µm + 700 µm = 1.2 mm.

Figure 5 represents a schematic perspective view of another detector designed in accordance with the present invention.

In the case of figure 5, the detector features a block (42) which consists of a stack of strips (44) made from an isolating (or highly resistive) converting material, for example, in ceramic or plastic, whereby the strips are separated from each other by lower spacers (46) and upper spacers (48).

These spacers are made of plastic, for example.

The spacers allow the slits (14) to be created between the strips, whereby the boundaries of each slit (14) are created by two adjacent plates, one lower spacer (46) and one upper spacer (48).

As was previously the case, the slits (14) are filled with an ionizable fluid, ionized by the particles released during the interaction of the incident ionizing radiation with the strips (44).

The block (42) also features a first conducting layer (49) and the second conducting layer (50) formed, respectively, on the first face and the second face of the block to create an electric field by raising the

first layer (49) to a first electric voltage and the second layer (50) to a second voltage which is greater than the first voltage, whereby the resulting electric field is used to extract the electrons created by ionization from block (42).

As was also the case in figure 3, one can replace the layers (49) and (50) by two electrically conducting grills, one at the first block face, and the other at the second block face.

As may be seen on figure 5, the layers (49) and (50) - or the grills - have slits, such as slits (51) located opposite slits (14) and thereby extending slits (14).

We shall now give some examples of manufacturing procedures for a detector designed in accordance with the precepts of the current invention.

If the block consists of alternating conducting/isolating layers, one begins by putting these layers against each other, by gluing them together, for example.

If the block is made from one single mass of this material, one begins by attaching the two conducting layers to the first and second faces, respectively, of this single isolating mass, by gluing them together, for example.

Once the block has been created, the slits are then formed by, for example, waterjet cutting, electrical discharge machining or roll-out stretch wire.

It should be specified that gluing has the advantage, especially in the case of waterjet cutting, of

preventing accidental dispersion of the waterjet between the layers during the cutting.

Before creating a slit, a guide hole may be created in the block, which will be used as a basis to create the slit using, for example, a waterjet applied through a nozzle, which is moved around with respect to the block.

Guide holes, which can be formed by, for example, chemical etching or some other technique, present the advantage of avoiding frontal shock when the waterjet is first turned on.

However, such guide holes are not necessary if the material used in the block does not crack.

Creating the slits is therefore a very rapid process.

Instead of using an ionizable gas, one can also use liquid, for example, Xe, or a supercritical phase such as CO_2, for example, (in supercritical phase).

Figure 6 illustrates a variation of figure 3. The detector in figure 6 features a supplementary isolating layer (6) formed on the last layer (4) located on the second face (8) of block (2) and an electrically conducting layer (4a) formed on this supplementary layer (6). The layer (4a) (through which slits (14) run, as is also the case for the adjacent layer (6)) is made of an absorbing electrical conducting material, whose role is to absorb the secondary particles created in the last layer (4), whereby the objective is to improve spatial resolution by preventing the secondary particles from directly penetrating into the avalanche gas

amplifications at a large angle (which would create a blur).

The detector, subject of the present invention, may be used, for example, for tomographic applications via positron emission (PET scanner with an incident energy of about 0.5 MeV) or in radiotherapy with energies of about MeV. If the incident radiation is made up of X-ray photons, the detector may be used in all situations where the photoelectric effect is negligible compared to the other types of interaction (for example, Compton effect or pair-creation effect).

The documents mentioned in the present description are:

[1] V. Perez-Mendez, S.I. Parker, IEEE Trans. Nucl. Sci. NS-21 (1974) 45

[2] S.N. Kaplan, L. Kaufman, V. Perez-Mendez, K. Valentine, Nuclear Instruments and Methods 106 (1973) 397

[3] AP Jeavons, G. Charpak, RJ Stubbs NIM 124 (1975) 491-503

[4] FR 2739941 A, "Détecteur de position, à haute résolution, de hauts flux de particules ionisantes". Invented by G. Charpak, I. Giomatris, Ph. Rebourgeard and J.P. Robert - See also international application WO 97/14173

[5] FR 2762096 A, " Détecteur de particules à électrodes parallèles multiples et procédé de fabrication de ce détecteur". Invented by G. Charpak, I. Giomatris, Ph. Rebourgeard and J.P. Robert - See also EP 0872874 A

[6] J.L. Gerstenmayer, D.Lebrun, and C. Hennion, "Multistep Parallel Plate Avalanche Chamber as a 2D imager for MeV pulsed radiography". SPIE Proceedings, vol. 2859, pages 107 to 114, SPIE symposium, 7-8 August 1996, Denver, Colorado

[7] J.L. Gerstenmayer, "High DQE performance X- and Gamma-ray fast imagers : emergent concepts", 1998 Symposium on Radiation Detection and Measurement, Ann Arbor, Michigan, 11 - 14 May 1998, Proceedings in Nuclear and Methods in Physics Research A.

CLAIMS

1. Bidimensional detector for incident ionizing radiation (9) consisting of primary particles whose energies are greater than, or equal to, 100 keV. The detector includes a block (2, 36, 42) of converting material capable of releasing secondary particles by interaction with the incident ionizing radiation, whereby the thickness of the block is at least equal to one-tenth of the mean free path traveled by the incident primary particles through the material. The detector is characterized by the fact that it has parallel slits (14) crossing the block, which are filled with a fluid capable of interacting with the secondary particles to produce tertiary particles equal in intensity and position to the incident radiation, whereby the block is positioned in such a manner as to ensure that the incident radiation comes in on the first block face (7) where the slits terminate.

2. Detector as described in claim 1, in which the slits (14) are perpendicular to the first face (7) of the blocks (2) and (36).

3. Detector as described in claim 1, in which the slit planes (14) form an angle (α) of between 1 ° and 5 ° with a line (Y) perpendicular to the first face (7) of the block.

4. Detector as described in any of the claims 1 to 3, in which the fluid is capable of being ionized by the secondary particles, thereby producing electrons which

may be considered tertiary particles, and moreover, the detector features the necessary technology (R1... Rn, 38 - 40) to create an electric field capable of extracting the tertiary particles, that is, the electrons, from the block.

5. Detector as described in claim 4, in which the fluid is a gas.

6. Detector as described in any of the claims 4 and 5, incorporating the necessary technology (24 - 26, 34) to analyze the electrons extracted from the block.

7. Detector as described in claim 6, in which the analysis techniques include an avalanche gas amplifier, capable of producing electrons avalanches (29) from the electrons extracted from the block.

8. Detector as described in claim 7, in which the fluid is a gas, and is capable of converting the electron avalanches into visible or ultraviolet radiation (30) and in which the analysis technology also features the necessary technology (34) to detect this visible or ultraviolet radiation.

9. Detector as described in claim 8, in which the technology used to detect the visible or ultraviolet radiation includes a camera (34) capable of detecting the visible or ultraviolet radiation, or, alternatively, a matrix of amorphous silicon photodiodes placed against the avalanche gas amplifier.

10. Detector as described in any of the claims 4 to 9, where the material is an electrical conductor and the block (2) is formed from stacked layers (4) of this

material, whereby these conducting layers alternate with electrically isolating layers (6) and the stack begins with a conducting layer (4) of the material on the first face (7) of the block and ends with a conducting layer (4) of the material on the second face (8) of the block, which is opposite the first face and on which the slits terminate. Moreover, the detector features the necessary technology (R1,... Rn) to apply electric voltages to the layers, with these voltages increasing gradually from the first face to the second face, thereby creating an electric field.

11. Detector as described in claim 10, with the addition of a supplementary layer (4a), formed on an additional electrically isolating layer (6), itself formed on the last layer (4) of the aforementioned material, located at the second face (8) of the block (2), whereby this supplementary layer (4a) and is made of an electrically conducting material capable of absorbing the secondary particles created in the last layer (4) and these supplementary layers (4a, 6) have slits running through them.

12 Detector manufactured according to claim 10, in which the layer (4) of the material located at the second face (8) of the block is blackened out to prevent parasitic light reflections.

13. Detector manufactured according to any of the claims 4 to 9, in which the material is electrically isolating, or highly resistive, the block (36) is created from stacked layers (37) of this material or,

alternatively, is made from one single mass of this material, whereby the block also features first and second layers or grills (38, 40) which are electrically conducting and formed, respectively, on the first block face (7) and second block face (8), the latter located opposite the first block face and on which the slits terminate. Under such a configuration, the electric field is created by raising the first layer or grill to a first voltage and the second layer or grill to a second voltage which is greater than the first voltage.

14. Detector as described in claim 1, in which the block (42) is made from a stack of strips (44) made from an isolating converting - or highly resistive - material, and the aforementioned strips are separated from each other by spacers (46, 48) which define the parallel slits (14) of the block, whereby the block also features first and second layers or grills (49, 50) which are electrically conducting and formed respectively, on the first block face (7) and second block face (8), the latter located opposite the first face and on which the slits terminate. Under such a configuration, the electric field is created by raising the first layer or grill to a first electric voltage and the second layer or grill to a second electric voltage which is greater than the first voltage.

15. Manufacturing process for the detector in of the claims 1 to 13, whereby the block (2, 36) is firstly manufactured and then the slits (14) are manufactured by one of the following techniques:

- waterjet cutting,
- electrical discharge machining
- roll-out stretch wire.

16. Manufacturing process as described in claim 15, for the manufacturing of the detector according to one of the claims 10 to 13, in which the layers (4 - 6, 37 - 38 - 40) are stuck to each other.

17. Manufacturing process as described in any of the claims 15 and 16, in which, before creating each slit (14), a guide hole is made in the block (2, 36) which is then used as a basis to create the slit.

ABSTRACT

Bidimensional detector of ionizing radiation and manufacturing process for this detector.

This detector consists of a block (2) created from a material which releases secondary particles by interaction with incident ionizing radiation (9) with an energy level greater than or equal to 100 keV. The thickness of the block is at least equal to one-tenth of the mean free path traveled by the incident radiation particles in the material. Parallel slits (14) run through the block which are filled with a fluid capable of interacting with the secondary particles to produce other particles representing the radiation. The block, and then the slits, are formed, for example, by waterjet cutting, electrical discharge machining or roll-out stretch wire. The invention can be used, for example, for radiographic purposes.

Figure 1.

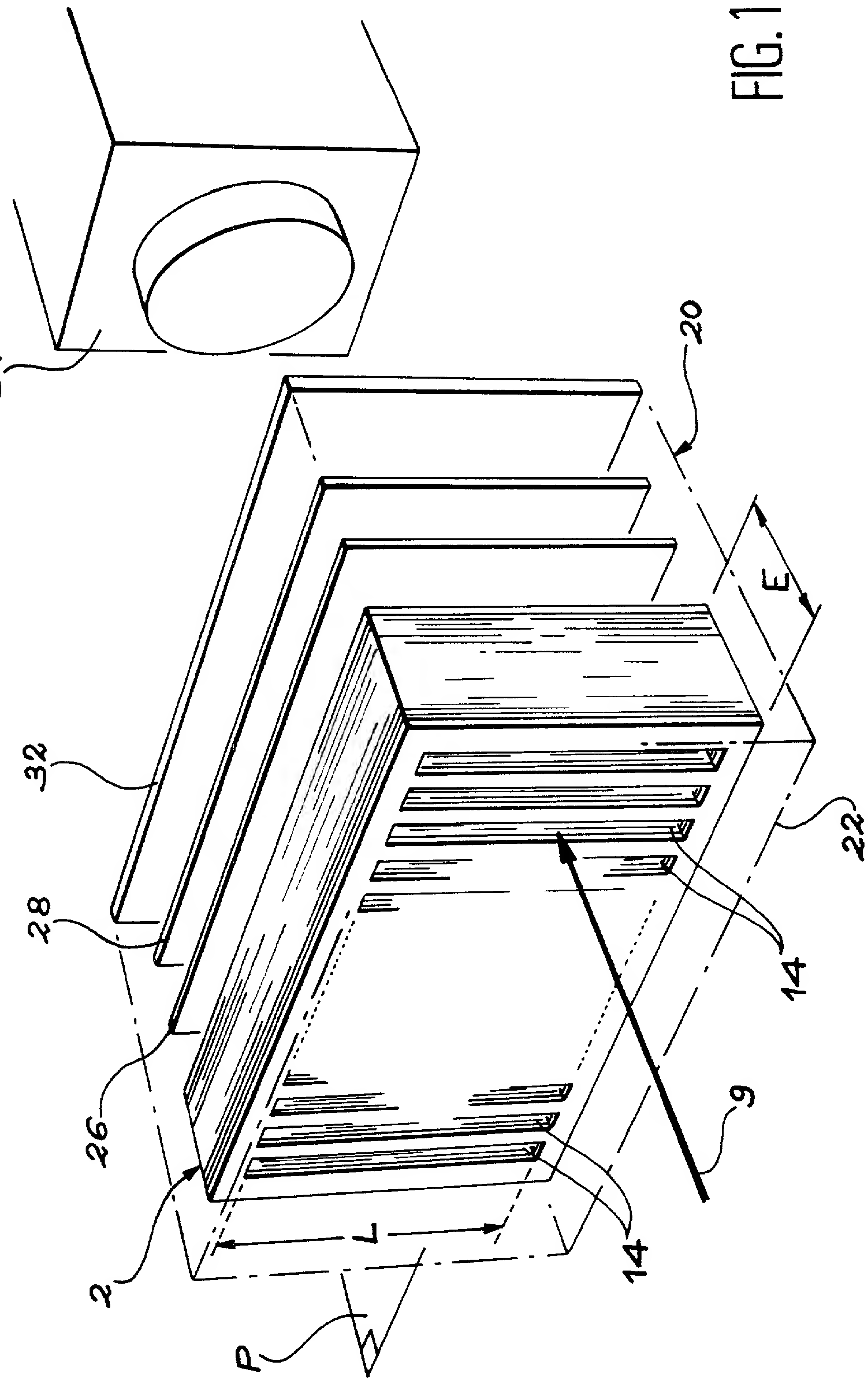

FIG. 1

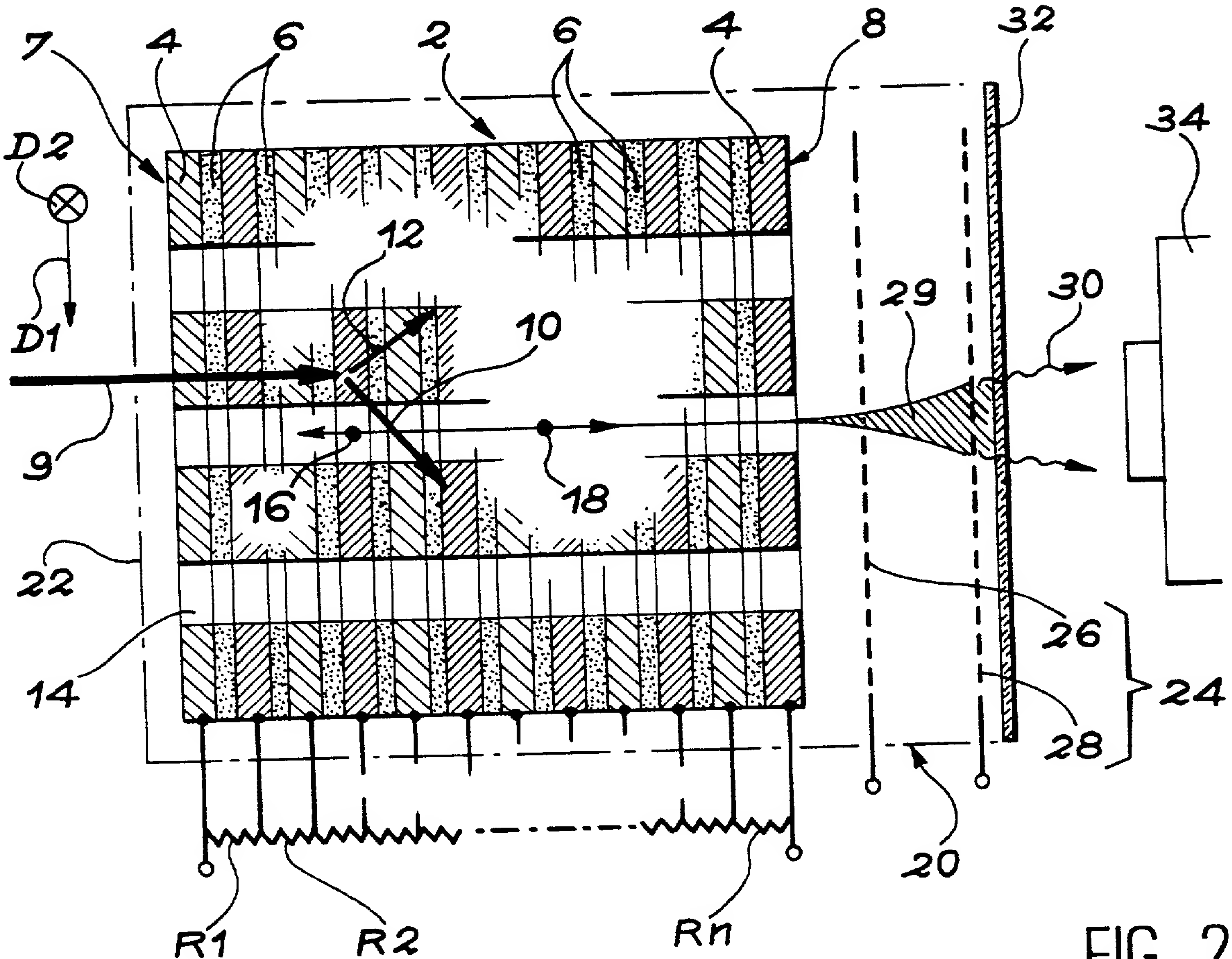
7
4
6
2
6
4
8
32
34
D2
D1
12
10
29
30
9
16
18
22
26
24
14
28
20
R1
R2
Rn

FIG. 2

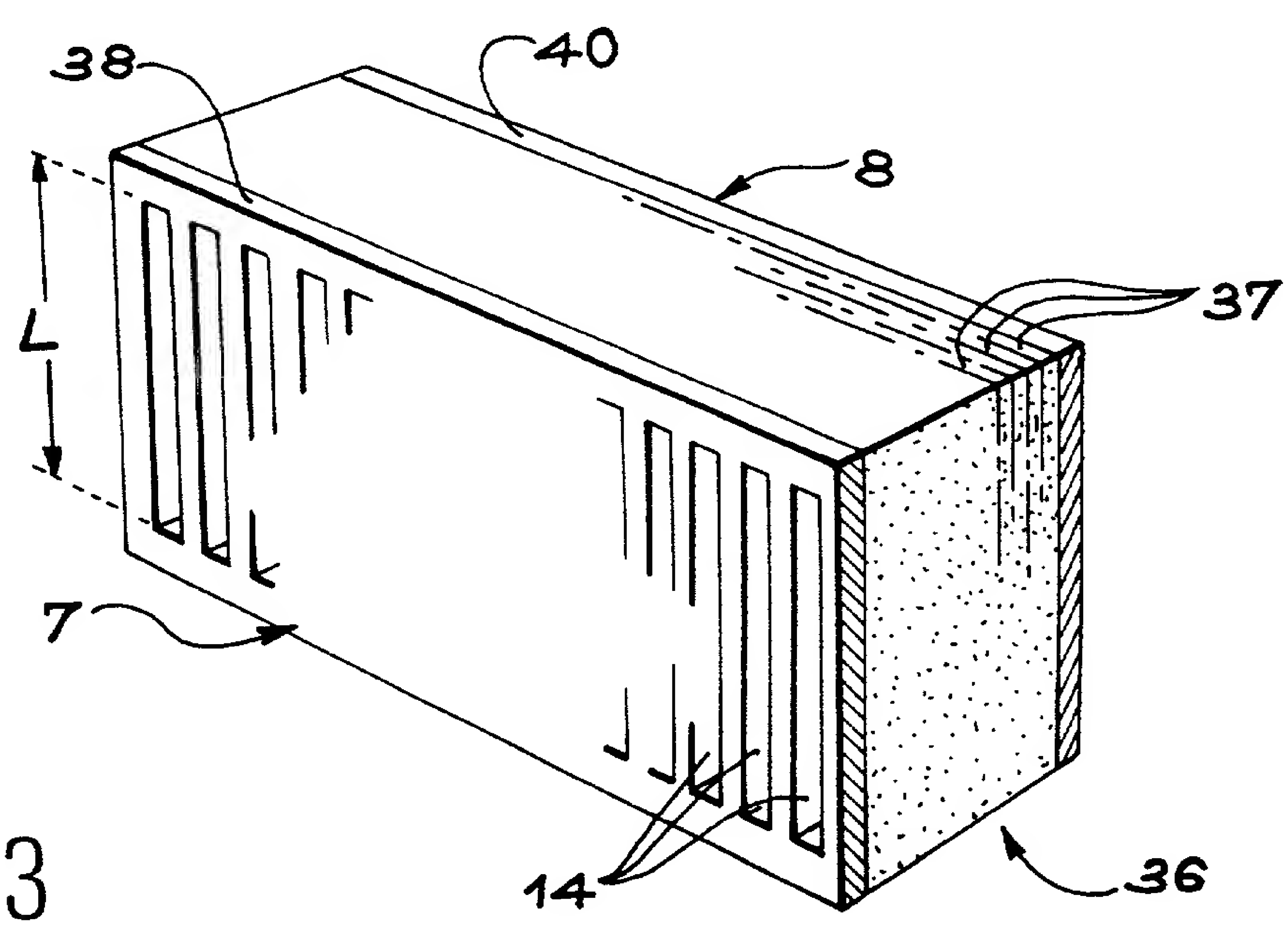
38
40
8
37
L
7
14
36

FIG. 3

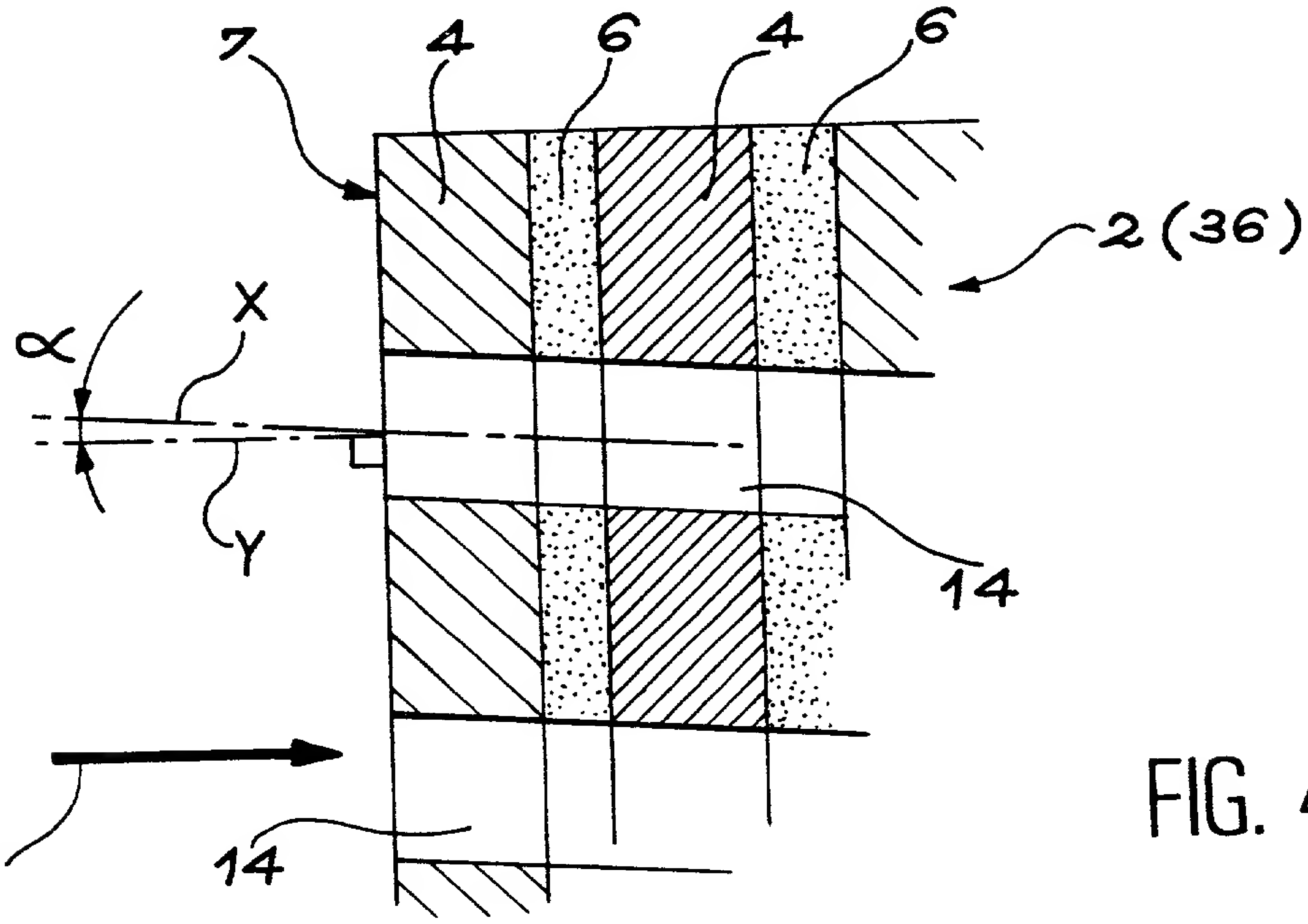

FIG. 4

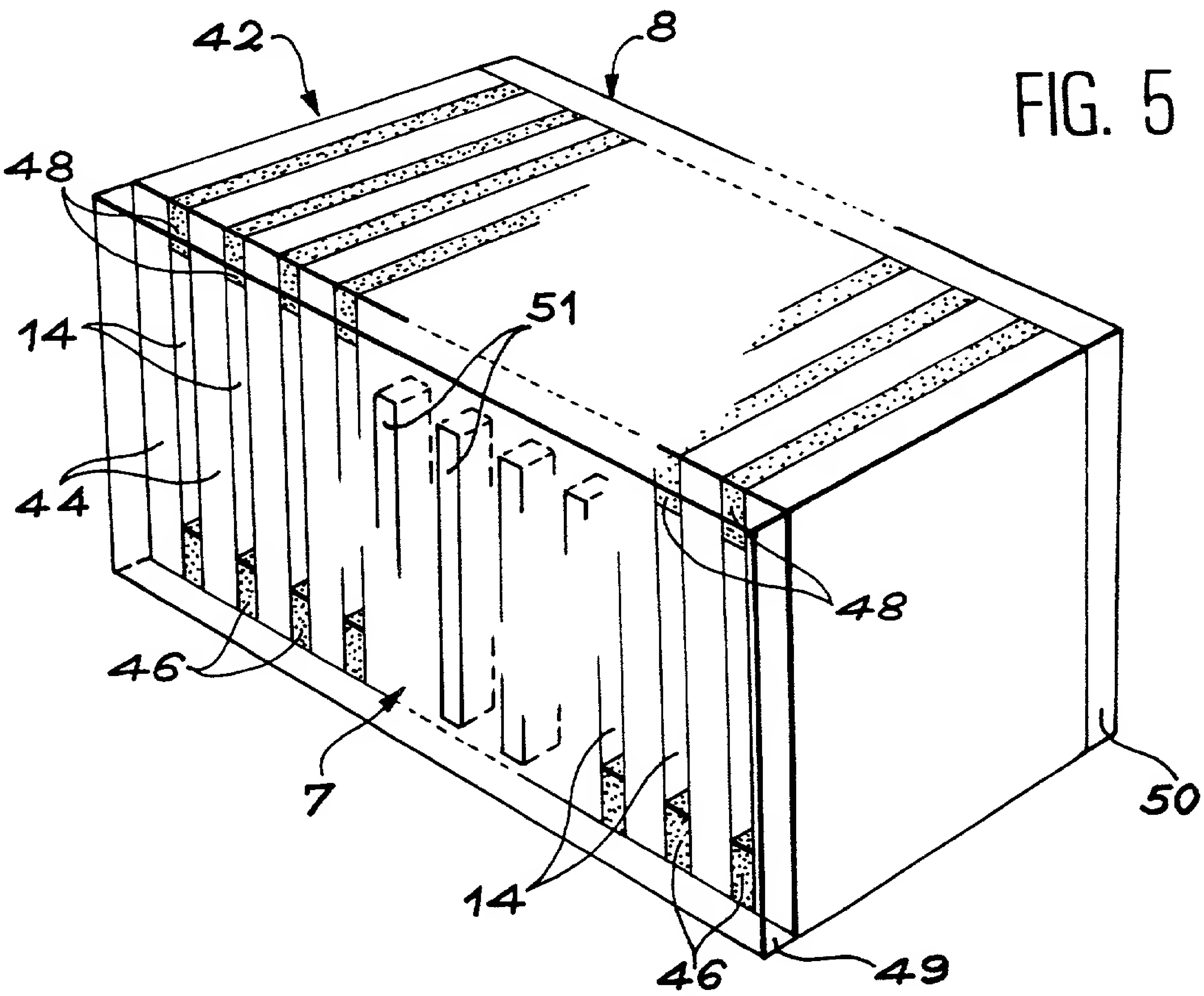

FIG. 5

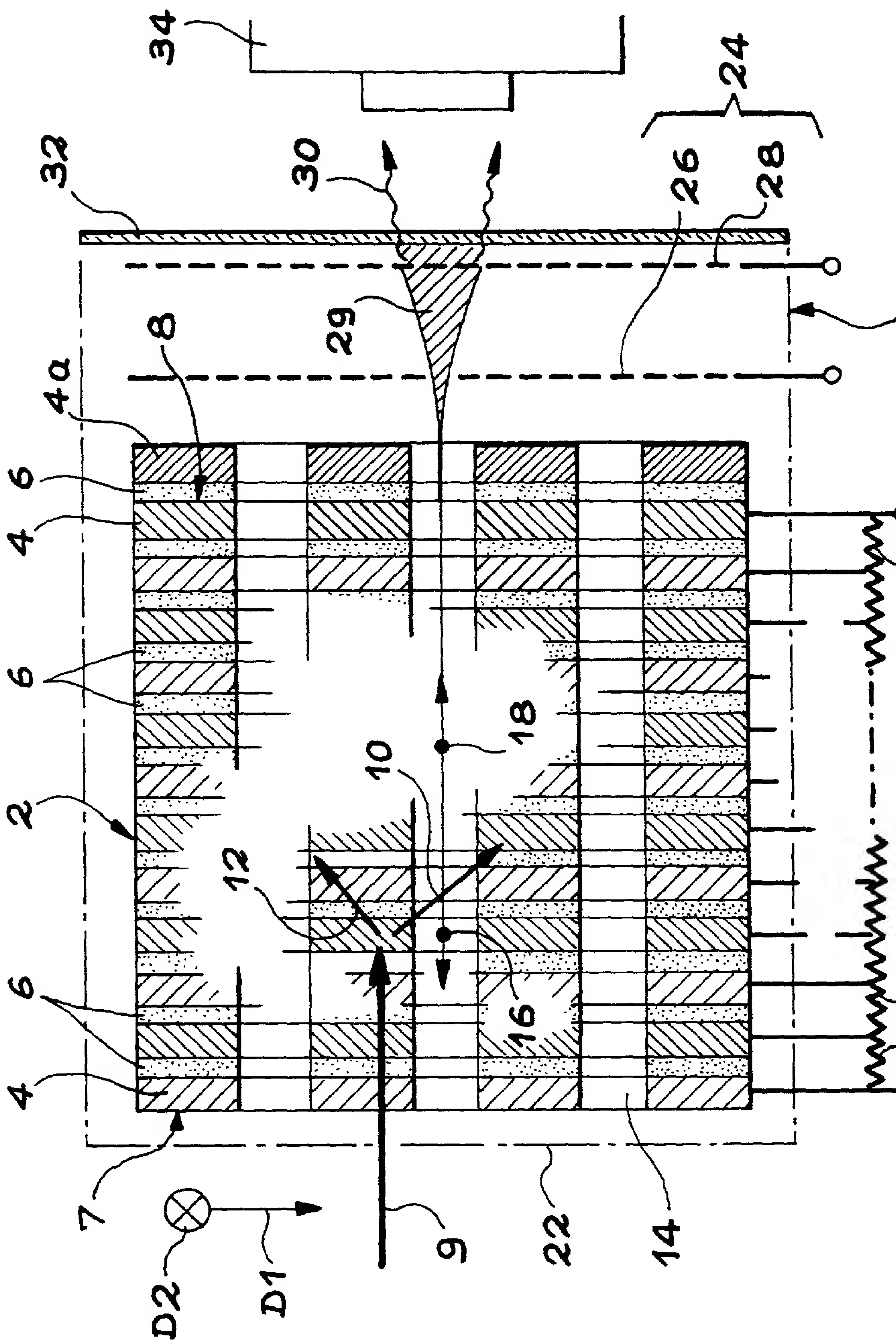

FIG. 6

B 13094.3 PV

Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

BIDIMENSIONAL DETECTOR OF IONIZING RADIATION AND MANUFACTURING PROCESS FOR THIS DETECTOR

the specification of which

☐ is attached hereto.

☐ was filed on

as Application Serial No.

and amended on

☒ was filed as PCT international application

Number PCT/FR00/00488

on February 23, 2000

and was amended under PCT Article 19

on November 27, 2000

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed	
99 02289	FRANCE	FEBRUARY 24, 1999	☒ YES	☐ NO
			☐ YES	☐ NO
			☐ YES	☐ NO
			☐ YES	☐ NO

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)

And we (I) hereby appoint : Norman F. Oblon, Registration Number 24,618; Marvin J. Spivak, Registration Number 24,913; C, Irvin McClelland, Registration Number 21,214; Gregory J. Maier, Registration Number 25,599; Arthur I. Neustadt, Registration Number 24,854; Richard D. Kelly, Registration Number 27,757; James D. Hamilton, Registration Number 28,421; Eckhard H. Kuesters, Registration Number 28,870; Robert T. Pous, Registration Number 29,099; Charles L. Gholz, Registration Number 26,395; Vincent J. Sunderdick, Registration Number 29,004; William E. Beaumont, Registration Number 30,996; Steven B. Kelber, Registration Number 30,073; Robert F. Gnuse, Registration Number 27,295; Jean-Paul Lavalleye, Registration Number 31,451; William B. Walker, Registration Number 22,498; Timothy R. Schwartz, Registration Number 32,171; Stephen G. Baxter, Registration Number 32,884; Martin M.,. Zoltick, Registration Number 35,745; Robert W. Hahl, Registration Number 33,893; and Richard L. Treanor, Registration Number 36,379; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C., whose post Office Address is : Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

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